ing behavior as diapausing *C. pipiens*, JH may initiate biting behavior in many of these insects.

The possibility that JH initiates biting behavior in *Anopheles freeborni* has already been suggested by Case *et al.* (*3*). They found that the JH mimic Methoprene stimulated both biting behavior and diapause termination. However, a second JH mimic (6,7-epoxygeranyl-4-ethylphenyl ether) failed to elicit biting despite diapause termination. Case *et al.* postulated that a natural JH might initiate biting in *Anopheles freeborni*, and that the discrepancy in results was due to differences in molecular structure between the mimics tested and natural JH's.

Recent studies suggest that JH is not the only hormone involved in the regulation of mosquito biting behavior. In *Aedes aegypti* and *Anopheles freeborni*, ovaries with developing eggs secrete a hormone that suppresses host-seeking or biting behavior between gonotrophic cycles (*15*). Whether this ovarian hormone influences JH synthesis to prevent biting during egg development is unknown.

ROGER W. MEOLA
RONALD S. PETRALIA
Department of Entomology, Texas A & M University, College Station 77843

References and Notes

1. R. W. Gwadz and A. Spielman, *J. Insect Physiol.* **19**, 1441 (1973); A. O. Lea, *ibid.* **14**, 305 (1968); R. W. Gwadz, L. P. Lounibos, G. B. Craig, *Gen. Comp. Endocrinol.* **16**, 47 (1971).
2. M. M. Lavoipierre, *Nature (London)* **181**, 1781 (1958); S. S. Chen, *Diss. Abstr. B* **30** (9), 4187-B (1969); J. G. Stoffolano, Jr., in *Experimental Analysis of Insect Behavior*, L. B. Browne, Ed. (Springer-Verlag, New York, 1974), p. 32.
3. T. J. Case, R. K. Washino, R. L. Dunn, *Entomol. Exp. Appl.* **21**, 155 (1977).
4. This long-day, warm-temperature regimen was selected to avoid any diapause-related effects on the corpus allatum of *C. pipiens* which might confuse interpretation of results. *C. quinquefasciatus*, a nondiapausing species, was also reared and maintained in this regimen.
5. Mosquito larvae (100 per 350 ml of tap water) were reared in covered plastic pans (27 by 19 by 6 cm) on a diet consisting of equal parts Brewer's yeast, lactalbumin, and finely ground laboratory animal chow. Daily rations varied with larval stage: newly hatched (day 0) and day 1, 150 mg; day 2 and day 3, 250 mg; day 4, 450 mg; and day 5, 250 mg.
6. A. O. Lea, *J. Insect Physiol.* **9**, 793 (1963).
7. R. Meola and A. O. Lea, *J. Med. Entomol.* **9**, 99 (1972).
8. A. Spielman, *ibid.* **11**, 223 (1974).
9. According to A. Clements [in *The Physiology of Mosquitoes* (Macmillan, New York, 1963), p. 69], egg maturation in mosquitoes is a two stage process. The resting stage represents the initial phase of follicular development to a point where the oocyte may be distinguished from the nurse cells. The second phase of development involves deposition of protein yolk which occurs after the mosquito feeds on blood.
10. A. O. Lea, *J. Insect Physiol.* **15**, 537 (1969).
11. Juvenile hormone-I (methyl-3,11-dimethyl-10, 11-cis-epoxy-7-ethyl-*trans,trans*-2, 6-tridecadienoate) was purchased from ECO Chemical Intermediates, ECO-Control, Inc., Cambridge, Mass.
12. P. Tate and M. Vincent, *Parasitology* **28**, 115 (1936); R. Wallis, *Proc. Entomol. Soc. Wash.* **61**, 219 (1959); H. Chapman, *Mosq. News* **21**, 324 (1961); S. Kawai, *Trop. Med.* **11**, 145 (1969); L. Sandburg and J. Larsen, *J. Insect Physiol.* **19**, 1173 (1973); A. Spielman and J. Wong, *J. Med. Entomol.* **10**, 319 (1973).
13. B. F. Eldridge, *Science* **151**, 826 (1966).
14. _____ and C. L. Bailey, *J. Med. Entomol.* **15**, 462 (1979).
15. M. J. Klowden and A. O. Lea, *J. Insect Physiol.* **25**, 231 (1979); R. Beach, *Science* **205**, 829 (1979); M. J. Klowden, *ibid.* **208**, 1062 (1980).
16. A. N. Franzblau, *A Primer of Statistics for Non-Statisticians* (Harcourt, Brace and World, New York, 1958).
17. Supported by U.S. Army Research and Development grant DAMD 17-79-C-9103. Approved as T. A. No. 12987 through the director of the Texas Agricultural Experiment Station. We thank C. Bailey, H. M. Kaska, L. L. Keeley, M. J. Klowden, and A. O. Lea for helpful comments.

9 April 1980; revised 17 June 1980

Have Tar and Nicotine Yields of Cigarettes Changed?

Abstract. *In official assays of the tar and nicotine yields of 12 popular brands of cigarettes, smoking machines took fewer puffs, on the average, in 1974 than in 1969. The decline in puffs appears to have been a major cause of the reported reductions in tar and nicotine yields during this period.*

Since 1967 in the United States and 1969 in Canada, the governments have sponsored regular assays of the "tar" and nicotine yield of cigarettes by means of smoking machines (*1*). These assays show that the tar deliveries of most cigarette brands have declined in the last 10 years (*2*). The value of the published figures has been criticized repeatedly, however, on the grounds that smokers can compensate for reduced deliveries by altering the way they smoke, for instance by taking more or larger puffs (*3*). Clearly, the advantages of switching to "milder" cigarettes depend on the degree to which smoking behavior remains unchanged. Similarly, fair comparisons of tar and nicotine deliveries require the behavior of the smoking machines to be held constant. We believe that a loophole exists in the standard smoking-machine procedure in that it does not specify the number of puffs to be taken. The number of puffs taken per cigarette for some brands declined significantly from 1969 to 1974, and we believe that this change has contributed to the reported reductions in their tar and nicotine content.

Many people may assume that, puff for puff, newer versions of popular brands (*4*) have been becoming weaker in tar and nicotine. The standard procedure, however, fixes neither the number of puffs taken on different brands during the same test nor the number taken on the same brand in subsequent tests. The procedure prescribes that a smoking machine (essentially a motorized syringe) take a 2-second 35-ml puff once each minute until a fixed butt length is reached (*5*). Number of puffs is determined, then, by the burn-time of the cigarette. Burn-time can be influenced, for example, by the porosity of the cigarette paper or the amount of tobacco in the cigarette.

The Federal Trade Commission (FTC) laboratory has not saved records of the number of puffs taken per cigarette in its tests (*6*), but in Canada such information has been kept, although it has never been studied systematically or published. We report here an analysis of puff data for 12 of the best-selling Canadian filter cigarettes, which accounted for 60 percent of the cigarette market in 1970 and 70 percent in 1974 (*7*). Our analysis was limited to the 11 Canadian surveys between 1969 and 1974, in which assays were done on the same machine and with the same analytical procedures (*2*, *8*).

For the 12 brands as a group, decreases in tar (actually "wet tar") (*2*) were strongly associated with decreases in the number of puffs taken by the smoking machine ($r = .97$, $P < .01$, d.f. = 4) (Fig. 1). There is a similar association between puffs and tar for each

Table 1. Comparison of the yields and weights (mean ± standard deviation) of 12 popular brands of Canadian cigarettes in survey I (1969) and survey II (1974). Paired *t*-tests (two-tailed) are used.

Item	Survey I (1969)	Survey II (1974)	Range of differences
Tar (mg)	21.8 ± 1.98	18.6 ± 2.24*	1.3 to 6.9
Nicotine (mg)	1.31 ± 0.14	1.15 ± 0.14†	.07 to .49
Weight (g)	1.12 ± 0.08	1.06 ± 0.08*	.03 to .11
Puffs	9.8 ± 1.1	8.8 ± 0.98*	.4 to 1.9
Tar per puff	2.24 ± 0.21	2.12 ± 0.22‡	−.04 to .30
Nicotine per puff	0.135 ± 0.011	0.131 ± 0.012‡	−.013 to .025

*$P < .002$. †$P < .01$. ‡Not significant.

0036-8075/80/0926-1550$00.50/0

brand across the 11 surveys. For the nine brands that showed a tar decrease of at least 1.8 mg from survey 1 to survey 11, the correlation coefficients (d.f. = 9) for puffs and tar ranged from .60 to .94 (mean = .79), all P's $\leq .05$, two-tailed; for the three brands that showed less than a 1.8 mg decrease in tar, the correlations ranged from .22 to .48 (mean = .35), none statistically significant. Two U.S. brands that were included in some or all of the surveys showed significant correlations between puffs and tar (Winston, $r = .99$, $P < .01$, d.f. = 3; Kool, $r = .93$, $P < .01$, d.f. = 9).

Table 1 shows the changes from the first survey in 1969 to the last in 1974. Overall, the cigarettes weighed less in 1974 than in 1969 and may have contained less tobacco. Tar dropped by 14.7 percent. One might expect that the simple index of tar per puff would correct the problems of comparing assays based on differing numbers of puffs. Unfortunately, the chemistry of cigarette smoke does not permit this easy solution. Tar delivery increases with each puff; therefore omission of the last few puffs can markedly alter the total tar delivery and the tar per puff (*9*). In one study of the same cigarettes, tar per puff after eight puffs was about 2.36 mg and after nine puffs was about 2.50 mg; thus a decrease of one puff caused a decrease of 5.6 percent in tar per puff (*9*). Note that a decrease of one puff from survey 1 to survey 11 caused a change of 5.4 percent in tar per puff. In contrast, nicotine delivery remains fairly constant with each puff on a cigarette (*9*). Consistent with this chemical fact, nicotine per puff did not change significantly from survey 1 to survey 11.

Given the numerous ways to reduce tar delivery, changes in number of puffs probably do not account for all the reduction in tar deliveries by specific brands over the last 20 years. Although we are unable to assess the relative contributions of other causes of tar reduction, the conclusion seems inescapable that a reduction in the number of puffs taken by smoking machines has been a major factor in the apparent decrease in cigarette toxicities from 1969 to 1974.

At least as early as 1958, scientists from the tobacco industry discussed the misleadingness and unfairness of assays based on differing numbers of puffs, arguing that 14 puffs should be required for a king-size cigarette and that the puff interval should be adjusted so as to achieve the proper butt lengths (*10*). Obviously, smoking-machine conditions based on a fixed number of puffs per cigarette provide more realistic estimates for those smokers who may be accustomed to obtaining a certain number of puffs from their cigarettes. If a smoker does have a habit of getting a certain number of puffs (or, equivalently, a certain total volume of smoke) per cigarette, the reduction in burn-time by roughly 10 percent should offer only slight impediment to getting all the smoke desired. (Imagine the success of a diet which permitted 9 minutes rather than 10 minutes to consume an ice cream cone.) Furthermore, in one study the number of puffs per cigarette taken by people in highly controlled laboratory settings had a standard deviation of 1.26 (mean = 8.5 puffs per cigarette) (*11*). It can be argued that if these smokers had been smoking a pack of 1974 cigarettes, often they would have smoked, in effect, a 1969, often a 1972 cigarette, and so on, depending on the number of puffs they took.

The results of standard smoking-machine assays are used extensively and often at face value by epidemiologists and other researchers interested in monitoring smoking habits and the hazards of smoking (*12*). In addition, the smoking public has been encouraged to select less hazardous brands based on tar : nicotine ratios (*13*), and the tobacco industry has been praised for a steady decline in these ratios (*14*). The reduction in these ratios for some brands, however, may be due to a decrease in the number of puffs taken during the assay; and, as a consequence, the value of the tar : nicotine ratio as an index of less-hazardous cigarettes may be more limited than has been supposed (*15*). It is important to be able to compare meaningfully and fairly the tar and nicotine deliveries of cigarettes from brand to brand and through the years. The present lack of attention to number of puffs per cigarette seems to violate the spirit of the assay, even though it strictly adheres to its letter. Since smoking machines automatically count puffs, the number of puffs taken per cigarette could be published (and listed on packets) along with the tar and nicotine deliveries. This revision would improve data for health researchers, policy-makers, and smokers (*16*).

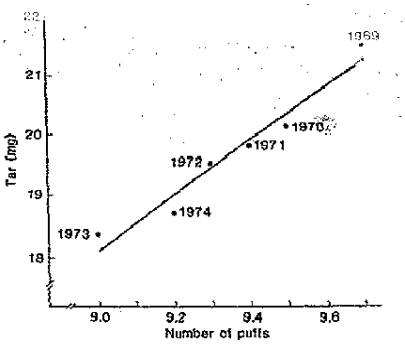

Fig. 1. Mean tar (tar = total particulate matter − nicotine) and mean number of puffs per cigarette for survey years 1969 to 1974 for 12 brands of filter cigarettes. If two surveys were conducted in one year, the data are based on the mean values. Linear regression: TPM = 4.44 (puffs) − 21.85, $r^2 = .94$. Smoking machines do take fractions of puffs (0.1 puff = 3.5 ml of smoke).

LYNN T. KOZLOWSKI
Clinical Institute, Addiction Research Foundation, Toronto, Ontario, Canada M5S 2S1
W. S. RICKERT, J. C. ROBINSON
Labstat Incorporated, Kitchener, Ontario N2C1L3
NEIL E. GRUNBERG
Department of Medical Psychology, Uniformed Services University of the Health Sciences, Bethesda, Maryland 20014

References and Notes

1. "Report of 'tar' and nicotine content of the smoke of 176 varieties of cigarettes" (Federal Trade Commission, Washington, D.C., 1979); "Tar, nicotine levels show some substantial reductions" (news release, Health and Welfare Canada, Ottawa, 29 March 1974).
2. FTC defines tar as total particulate matter (TPM) minus water minus nicotine; the Canadian Cigarette Testing Laboratory has used the FTC definition since 1972 but originally defined tar as TPM minus nicotine. In this report, "tar" or "wet tar" will refer to the original Canadian definition.
3. H. Ashton and D. W. Watson, *Br. Med. J.* 1970-III, 679 (1970); S. J. Green, in *Smoking Behaviors*, R. E. Thornton, Ed. (Churchill Livingstone, Edinburgh, 1978), p. 380; L. T. Kozlowski, M. E. Jarvik, E. Gritz, *Clin. Pharmacol. Ther.* 17, 93 (1975); S. R. Sutton *et al.*, *ibid.* 24, 40, 395 (1978).
4. The newer, extremely low-tar cigarettes (1 mg tar) are not considered in this report because they have contributed to the decline in national tar deliveries.
5. The butt length is 23 mm in the United States and 30 mm in Canada; if the length of the filter plus its overwrap is greater than these figures (and in many brands it is), 3 mm is added to the butt length.
6. H. Pillsbury, Federal Trade Commission, personal communication.
7. Belvedere king size filter, Cameo king size filter, Craven A king size filter, Du Maurier king size filter and regular filter, Export A regular filter, Mark Ten king size filter and regular filter, Number 7 king size filter, Peter Jackson king size filter, Players regular filter, Rothmans king size filter.
8. The Canadian Cigarette Testing Laboratory was moved from the Department of Statistics, University of Waterloo, in October 1977 to Labstat Incorporated, a private corporation.
9. R. M. Wiley and J. G. Wickham, *Tob. Sci.* 18, 67 (1974).
10. E. H. Keith and J. R. Newsome, *ibid.* 2, 14 (1958).
11. J. E. Henningfield and R. R. Griffiths, *Behav. Res. Methods Instrum.* 11 (No. 6), 538 (1979).
12. G. B. Gori and C. J. Lynch, *J. Am. Med. Assoc.* 240, 1255 (1978); E. C. Hammond and L. Garfinkel, *Environ. Res.* 12, 263 (1976).
13. M. A. H. Russell, *Br. Med. J.* 1976-I, 1430 (1976).
14. R. Stepney, *Lancet* 1979-II, 422 (1979).
15. Tar yields change more rapidly than nicotine yields do as a function of puffs (*9*).
16. Smokers might like to calculate the "unit-price" (price per puff) of their cigarettes.

17. We thank M. Pope, R. C. Frecker, D. Zilm, A. Wilkinson, and K. Wagner for advice and assistance.

4 July 1980